Assessing The Impact Of A School-Based Water Treatment, Hygiene And Sanitation Programme On Pupil Absence In Nyanza Province, Kenya: A Cluster-Randomized Trial

By: Matthew C. Freeman, Leslie E. Greene, Robert Dreibelbis, Shadi Saboori, Richard Muga, Babette Brumback, and **Richard Rheingans**

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Objectives: There has been increased attention to access to water, sanitation and hygiene (WASH) at schools in developing countries, but a dearth of empirical studies on the impact. We conducted a cluster- randomized trial of school-based WASH on pupil absence in Nyanza Province, Kenya, from 2007 to 2008.

Methods: Public primary schools nested in three geographical strata were randomly assigned and allocated to one of three study arms [water treatment and hygiene promotion (WT & HP), additional sanitation improvement, or control] to assess the effects on pupil absence at 2-year follow-up.

Results: We found no overall effect of the intervention on absence. However, among schools in two of the geographical areas not affected by post-election violence, those that received WT and HP showed a 58% reduction in the odds of absence for girls (OR 0.42, CI 0.21–0.85). In the same strata, sanitation improvement in combination with WT and HP resulted in a comparable drop in absence, although results were marginally significant (OR 0.47, 0.21–1.05). Boys were not impacted by the intervention.

Conclusion: School WASH improvements can improve school attendance for girls, and mechanisms for gendered impacts should be explored. Incomplete intervention compliance highlights the challenges of achieving consistent results across all settings.

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conclusion School WASH improvements can improve school attendance for girls, and mechanisms for gendered impacts should be explored. Incomplete intervention compliance highlights the challenges of achieving consistent results across all settings.

keywords school, water treatment, sanitation, hygiene, water, sanitation and hygiene, absence

Introduction

More than 850 million people in the world lack access to a water supply, and more than 2.5 billion lack access to sanitation facilities (WHO and UNICEF, 2010). There is a robust evidence of the impact of improvements in access to water, sanitation and hygiene (WASH) at home on the health of children under 5 years. (Curtis & Cairncross 2003; Fewtrell *et al.* 2005; Rabie & Curtis 2006; Clasen *et al.* 2007, 2010). However, few studies have been conducted to assess the impact of improved WASH conditions on school-age children.

Improved school WASH conditions – for example, increasing water quality, and quantity, hygiene education, provision of soap, improved latrine access or cleanliness – may reduce pupil absence by providing services and a learning environment that appeals to children, specifically girls who are menstruating without facilities for personal hygiene, and by reducing illness transmission (Pearson & Mcphedran 2008). School absence can be a proxy for health status among children in developed countries (Houghton 2003). Absence is associated with reduced academic performance, drop-out rates and general delays in academic and social development, although most data come from middle- and upper-income countries (Lamdin 1996; Reid 2003; Bener *et al.* 2007; Kearney 2008).

A limited number of studies in low-income settings have explored the role of school-based handwashing or water treatment in reducing absence by between 21% and 42% (Bowen *et al.* 2007; O' Reilly *et al.* 2008; Blanton *et al.* 2010). In developed countries, mandatory handwashing with soap may reduce rates of reported illness-related absence (Nandrup-Bus 2009), and provision of alcohol-based hand sanitizers in school has been shown to reduce absence by 20 – 51% (Hammond *et al.* 2000; Dyer 2001; White *et al.* 2001; Guinan *et al.* 2002; Morton & Schultz 2004; Sandora *et al.* 2008). A number of these studies have limitations such as small sample sizes, no adjustment for school-level clustering or utilization of non-equivalent groups designs (Meadows & Saux 2004). An 11% reduction in absence for girls in Bangladesh, frequently cited in the literature as evidence of impact for improved sanitation, is from a non-experimental design that included monetary subsidies for parents (UNICEF, 1994).

Here, we seek to address the evidence gap by evaluating the impact of a comprehensive school-based WASH programme on absence among primary school children in western Kenya. Further, we explore gender-specific effects. Additional outcomes and impact measures include improvements in WASH facility access, enrolment and test scores.

Methods

Setting

The study area consisted of eight divisions in four districts of Nyanza Province. The population of Nyanza Province is 6.3 million, in which 29% are primary school-age children (Kenya National Bureau of Statistics (KNBS) & ICF MACRO (2010). The study area was based on a rapid assessment conducted by the study partners in 2007; contiguous divisions were assigned to three geographical strata – Nyando/Kisumu East, Rachuonyo and Suba Districts (Figure 1). A stratified design was employed to capture the differential impact of the intervention on variable baseline conditions. The study was embedded within a larger applied research and learning project led by the international non-governmental organization CARE, designed to develop, test and promote improved WASH in schools programming.

School selection

All Government of Kenya (GoK) primary schools (n = 1084) in four districts received surveys to assess their water and sanitation conditions; surveys were returned by 904 (83%) schools. Eligible schools were those that exceeded the GoK standard for pupil-to-latrine ratio (25:1 for girls and 30:1 for boys) and had a water source within 1 km during the dry season (Republic of Kenya Ministry of Education 2008). Schools that did not meet the latter criterion were considered 'water scarce' and were eligible for a different study. These criteria were recommended by implementing partners and government stakeholders and are consistent with internationally recognized school

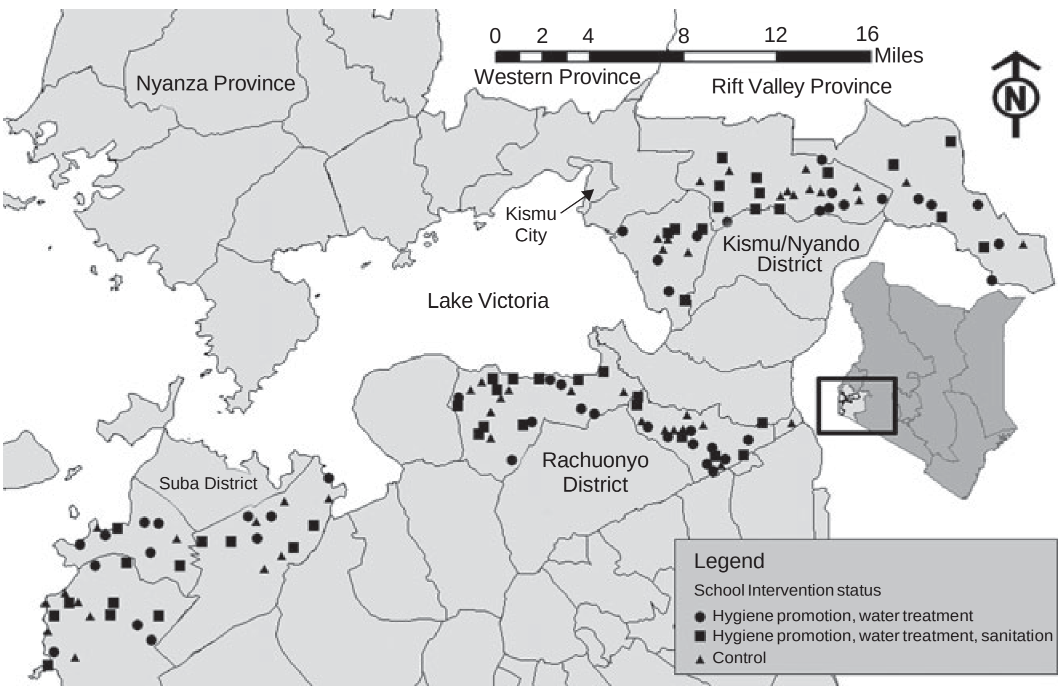

Figure 1 Map of intervention area and school locations in Nyanza Province, Kenya.

standards (UNICEF, 2004). Of the 198 eligible schools, 135 were randomly selected and randomly assigned to one of three study arms after baseline evaluation. Arm 1 was hygiene promotion and water treatment (HP & WT), arm 2 was HP & WT plus sanitation and arm 3 was the control group, which received all interventions at the conclusion of the study (Figure 2).

Intervention

Schools in the HP & WT intervention arm received a 3-day training of teachers on HP, behaviour change and WT methods and regular follow-up visits throughout the school year. The programme provided handwashing and drinking water containers and a one-time, 1-year supply of WaterGuard (a 1.2% chlorine-based point-of-use water disinfectant promoted by Population Services International). Schools in the second intervention arm received components listed above, in addition to provision of latrines to the GoK pupil:latrine standard with a maximum of seven latrines. HP & WT were completed in May – June 2007, while sanitation construction was completed from May – November 2007. All students in both intervention and control schools were dewormed after the baseline, in May 2007, and in June 2008 with a single 400 mg dose of albendazole.

Data collection

We collected data at baseline (February – March 2007) and after implementation (September – October 2008). Structured interviews were conducted with pupils in the Dholuo language to ascertain absence and WASH knowledge, attitudes and practices. School absence (and duration of absence) was measured using 2-week pupil-reported absence. Previous studies have assessed pupil absence through teacher records, an approach we found problematic in many schools. Formative research revealed >95% specificity and sensitivity for 2-week pupil-reported ab-

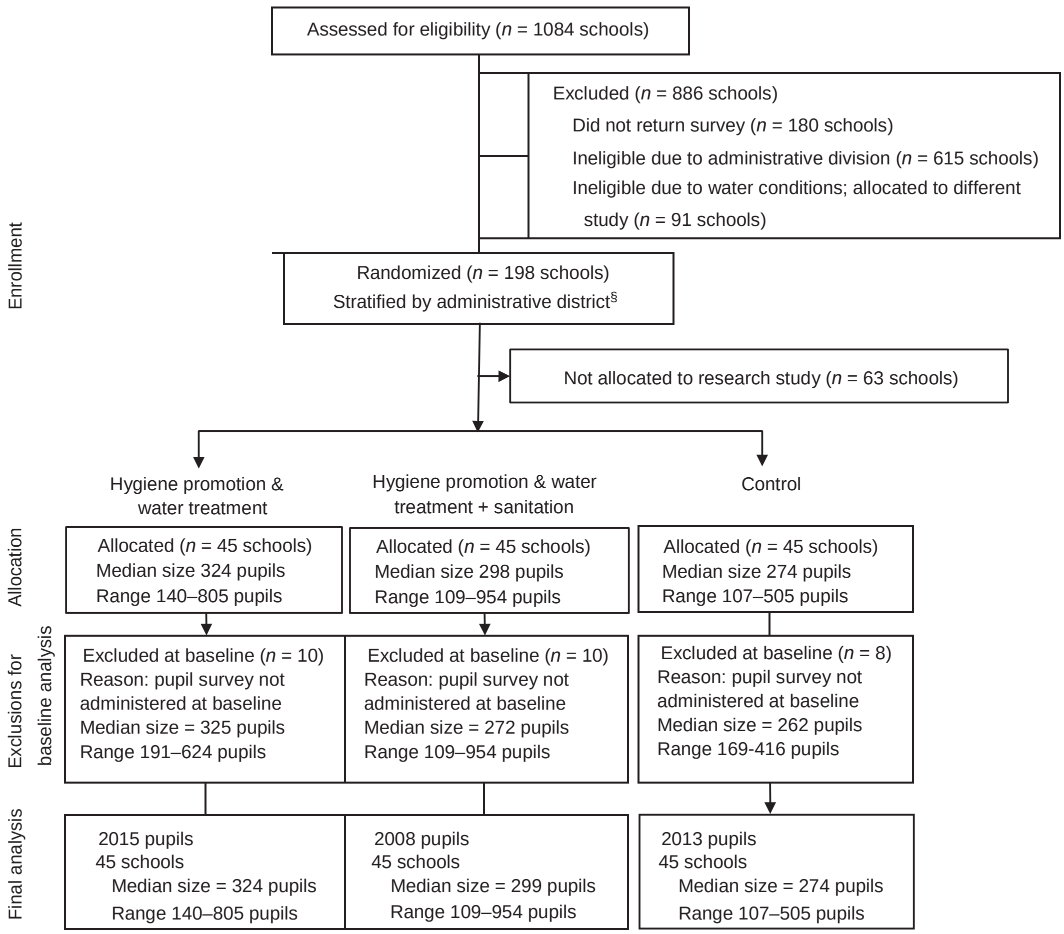

Figure 2 School and pupil selection.

sence (Freeman, unpublished data). At follow-up, we conducted a roll-call assessment of absence for all registered students the day of the field visit to assess the validity of our primary absence measure.

We based our sample size calculation on the 29% reduction in the absence found in previous studies, assuming a baseline rate of 24% and an intra-class correlation of 0.04 (O' reilly *et al.* 2008). We calculated a minimum sample size of 25 pupils per school and 45 schools per intervention arm using $a = 0.05$, $b = 0.2$. At each data collection round, pupils in each school from grades 4 – 8 were randomly selected from class rosters using systematic random sampling. As a result of time constraints, 107 schools were randomly selected for the pupil baseline study.

Other data were collected via structured interviews in English with head teachers and structured observation of school WASH facilities. Because of post-election violence in Kenya from January – March 2008, we surveyed head teachers and community leaders in April 2008 to assess the extent of migration and destruction of property in our study communities. Scores from the Kenya Certificate of Primary Education (KCPE) examinations – yearly country-wide examinations administered to primary school children in grade eight – were secondary impact measures, collected from official records in December at pre-intervention (2006) and post-intervention (2007 and 2008). Enrolment was collected each January for pre-intervention (2007) and post-intervention (2008 and 2009).

A systematic sample of households in each school's surrounding community was selected for data collection. Heads of household having at least one primary school-aged child were interviewed. Trained enumerators assessed both reported and observed household WASH conditions and demographic characteristics, including a list of household assets using categories identified in the Kenya Demographic and Health Survey (Gwatkin *et al.* 2000). Household variables were aggregated for use as community-level (i.e. school) covariates in multivariable analysis. Data were collected using handheld digital devices.

Ethics approval was received from the Institutional Review Board of Emory University (Atlanta, GA, USA), and permissions for the programme and trial were granted by the GoK Ministries of Health, Water and Irrigation, and Education. A waiver of parental consent was granted; head teachers of each school signed an *en loco parentis*. Oral assent was obtained from all participants.

Data analysis

Data were cleaned and analysed in sas v9.2 (Cary, NC, USA) and stata v10 (College Station, TX, USA). Latrine quality scores and household wealth scores were constructed through principal component analysis (Vyas & Kumaranayake 2006). Three observed latrine variables (scaled scores for smell, flies and dirtiness) were reduced to an index identifying maintenance quality. School latrines without excess smell, flies or presence of faeces were considered 'acceptable'.

To estimate the impact of the intervention on school absence, we employed multivariable logistic regression. Standard errors and confidence intervals were adjusted to account for clustering of students within schools and stratification of geographical districts. Probability weights reflected disproportionate sampling of students within schools. The regression models took the form:

$$\frac{\log p_{\mathrm{tij}}}{1 - p_{\mathrm{tij}}} = a + ct + G_{1i}d_1 + G_{2i}d_2 + G_{1i}h_1 t + G_{2i}h_2 t$$

where (p_{tij}) is the probability of school absence of individual j from school i at time t, G_{1i} indicates assignment to treatment group 1 (HP & WT) and G_{2i} indicates assignment to treatment group 2 (HP & WT + San). The parameters h_1 and h_2 represent the treatment effects of primary interest, which compare each of group 1 and 2 *vs.* control. Specifically, we are comparing the logit probability of absence at follow-up in a treatment group with a hypothetical version of what it would have been had the same group been assigned to control. We tested whether the treatment effects differed across geographical strata. Models included key pupil covariates together with baseline-level school and aggregate community cluster-level variables determined *a priori* to model fitting.

We used the reported number of days of absence in the previous 2 weeks to estimate the number of days of absence avoided per pupil per year by the intervention. We calculated the change in attendance between baseline and follow-up in the intervention schools and compared it with that of the control schools; that difference in our 2-week study period was extrapolated to the school year. Secondary outcome and impact variables – enrolment and test scores – were analysed by *t*-test comparison between intervention and control schools on the school-level change from baseline to final.

Results

Baseline school, pupil and community characteristics and post-election violence

Research participants were 6036 pupils in 135 primary schools at baseline (2619) and follow-up (3417). Baseline characteristics are presented in Table 1. Key factors were similar between intervention and control groups at

Table 1 Comparison of aggregate school, pupil and household characteristics at baseline between schools in intervention and control study arms

Variable	HP & WT	HP & WT + sanitation	Control
Pupil demographics*	n = 35	n = 36	n = 36
Age	13.3 (0.4)	13.2 (0.6)	13.4 (0.7)
Grade	5.5 (0.3)	5.9 (0.3)	6.0 (0.5)
Report having a latrine at home	67 (25)	72 (22)	64 (30)
School conditions	n = 45	n = 44	n = 44
Pupils per teacher	33 (10)	33 (12)	28 (7)
Proportion of girls enrolled	48 (3)	48 (4)	48 (4)
Electricity at school (%)	2 (4)	2 (4)	0 (0)
Iron sheet roofing throughout school (%)	45 (100)	43 (98)	43 (98)
Cement floor throughout school (%)	13 (29)	10 (22)	5 (11)
School current water source is improved† (%)	20 (45)	13 (30)	18 (41)
Distance to school current water source in metres	148 (330)	184 (489)	117 (215)
School dry season water source is improved† (%)	11 (24)	13 (30)	16 (36)
Distance to school dry season water source in metres	1191 (1322)	865 (964)	1015 (1307)
Pupil-to-latrine ratio < 3 times government standard			
Boys:latrine > 90:1 (%)	12 (27)	13 (29)	5 (11)
Girls:latrine > 75:1 (%)	12 (27)	12 (27)	7 (16)
Household demographics*	n = 45	n = 45	n = 45
Female-headed households	30 (17)	33 (17)	29 (16)
Female head of household completed primary school	48 (18)	46 (18)	46 (16)
Distance to school from home in minutes	19 (9)	18 (6)	18 (6)
Household respondent used soap during handwashing demo	72 (15)	70 (19)	68 (20)
Household currently using protected drinking water source†	64 (31)	64 (30)	66 (32)
Household currently using improved drinking water source†	62 (30)	62 (29)	65 (32)
Latrine coverage in community†	38 (22)	39 (23)	38 (21)
Per cent households in poorest wealth quintile	19 (13)	23 (15)	23 (14)
Per cent households in least poor wealth quintile	22 (15)	17 (18)	15 (11)

Data are means (SD) or numbers (%).
*Mean and (standard deviation) calculated from cluster-level means or proportions.
†Improved sources include boreholes, rainwater harvesting tanks, protected springs and protected wells (WHO 2010).
†Improved latrine coverage are latrines within compound or home (WHO 2010).

baseline, with some exceptions, including enrolment, cement flooring and the percentage of schools, which at baseline exceeded the GoK pupil-to-latrine ratio by three times.

The survey of disruption because of post-election violence revealed 'some' or 'severe' destruction of property in the Nyando/Kisumu geographical stratum (43%), as compared to 4% in Rachuonyo and 7% in Suba ($P < 0.001$). There was no statistical difference between intervention packages ($P = 0.08$). Some or severe migration occurred in all geographical strata, though it was greater in Nyando/Kisumu East (47%) than Rachuonyo (24%) or Suba (29%), ($P = 0.02$).

Changes in pupil behaviour and knowledge and school conditions

We found significant and substantial differences in pupil WASH knowledge between intervention and control groups after the intervention (Table 2). Knowledge of key handwashing times and scores on a handwashing demonstration in intervention schools significantly increased. Intervention schools – where no water supply improvement or soap was provided – significantly improved in consistent provision of drinking water, handwashing water and soap, as compared to control schools. Schools that received latrines approximately halved their pupils-to-latrine ratio, but few achieved the GoK standards.

Although there were significant differences between intervention and control groups at follow-up, a substantial proportion of school improvements did not meet standards necessary to be considered fully compliant. Fewer than 40% of pupils in schools from either intervention arm reported that soap was always available; approximately 60% reported that water was always treated; and >75% reported drinking water was always available.

Table 2 Comparison of pupil and school water, sanitation and hygiene (WASH) characteristics among schools that received hygiene promotion (HP), water treatment (WT), sanitation and controls at baseline and follow-up

Variable	HP & WT			HP & WT + sanitation			Control	
	Baseline $n = 45$	Follow-up $n = 45$	P-value*	Baseline $n = 45$	Follow-up $n = 45$	P-value*	Baseline $n = 45$	Follow-up $n = 45$
Pupil knowledge and practice variables†								
Mention two key handwashing times (before eating, after defaecation)	72 (15)	83 (10)	0.09	73 (18)	85 (10)	0.05	75 (14)	78 (12)
Score out of six during handwashing demonstration	3.8 (0.7)	4.5 (0.6)	0.03	3.8 (0.6)	4.6 (0.5)	<0.001	3.8 (0.7)	4.1 (0.5)
Know all correct steps of water treatment	10 (14)	32 (17)	0.67	9 (10)	29 (15)	0.52	7 (9)	32 (19)
School WASH characteristics								
Pupils report drinking water always available	15 (24)	66 (27)	<0.001	19 (23)	74 (22)	<0.001	16 (20)	29 (32)
Pupils report handwashing water always available	16 (24)	68 (26)	<0.001	16 (21)	76 (22)	<0.001	12 (17)	22 (26)
Pupils report soap always available	1 (4)	36 (28)	<0.001	1 (3)	41 (27)	<0.001	2 (10)	2 (7)
Drinking water available day of field visit	24 (53%)	33 (73%)	<0.001	17 (38%)	37 (82%)	<0.001	23 (52%)	8 (18%)
Detectable chlorine residual in drinking water provided to pupils day of field visit	2 (5%)	28 (62%)	<0.001	1 (2%)	30 (67%)	<0.001	0 (0%)	0 (0%)
Soap available day of field visit	0 (0%)	15 (34%)	<0.001	0 (0%)	21 (45%)	<0.001	0 (0%)	0 (0%)
Handwashing water available day of field visit	7 (16%)	32 (71%)	<0.01	1 (2%)	36 (80%)	<0.001	4 (9%)	2 (4%)
Girls per latrine	59 (32)	56 (25)	0.75	77 (67)	40 (25)	<0.001	57 (40)	50 (20)
Boys per latrine	67 (36)	57 (30)	0.43	82 (58)	44 (28)	<0.001	57 (38)	55 (26)
Number of acceptable latrines‡	4.6 (2.9)	6.8 (3.6)	0.68	3.8 (3.0)	9.7 (5.1)	<0.001	3.6 (2.7)	5.4 (2.9)

Data are mean (SD) or number (%) of school-level aggregate data.
*P value of logistic or linear regression coefficient on the difference between follow-up and baseline compared with controls.
†Aggregated school-level means.
‡Latrine does not have excess smell, flies or visible faeces.

Impact analysis: absence and educational outcomes

A total 5989 (>99%) children supplied absence information. There were substantial declines in pupil-reported absence in all geographical strata (Table 3); however, in Nyando/Kisumu, absence in both intervention and control arms approached zero, making accurate estimation difficult.

Multivariable analyses of the effect of the programme on pupil-reported absence overall and stratified by gender, along with interaction terms for geographical strata, are reported in Table 4. We found no significant impact on absence owing to the HP and WT intervention [odds ratio (OR) 0.81, 95% confidence interval (CI) 0.50 – 1.35], nor with the addition of sanitation (OR 0.97, CI 0.55 – 1.69) (Table 4). When the analysis was stratified by gender, the impact on girls was suggestive of an effect, but also not statistically significant (OR 0.63, CI 0.31 – 1.27).

We found significant interaction of the intervention impact between the Nyando/Kisumu stratum and the other two strata. As a result of the substantial secular reduction in absence for Nyando/Kisumu, significant effect modification by geographical strata and issues of post-election disruption to the study population, additional analyses were restricted to only the Suba and Rachuonyo strata.

The Rachuonyo/Suba strata unadjusted results reveal that schools that received WT and HP had a 39% reduction in pupil absence (OR 0.61, CI 0.37 – 1.00), while those that received an additional sanitation component in conjunction with HP and WT showed a reduction of 27% (OR 0.73, 95% CI 0.42 – 1.28) compared with controls. When modelled with covariates, estimates were comparable (Table 5, Model 2).

Stratified analysis by gender suggests that the impact of the HP & WT intervention (with and without additional sanitation) is more effective in reducing absence among girls than among boys (Table 5, Model 3). Among girls, HP and WT alone revealed a 58% reduction in the odds of 2-week absence (OR 0.42, 95%CI 0.21 – 0.85), but no effect for boys (OR 0.88, 0.45 – 1.71, data not shown). Schools that received HP & WT in addition to sanitation showed comparable benefit for girls (OR 0.47, 0.21 – 1.05) and not boys (OR 0.98, 95% CI 0.52 – 1.87). There was no significant difference between the intervention arms (HP & WT vs. HP & WT + San). Analysis of reported absence because of illness showed similar effects for girls (HP & WT: OR 0.47, 95% CI 0.19 – 1.17; HP & WT + San: OR 0.46, 95% CI 0.18 – 1.17), although estimates were not statistically significant.

The difference in the difference for the number of days of absence avoided for girls was 0.34 days per pupil per 2-week recall period for HP & WT and 0.38 for HP & WT and sanitation (Data not shown). We estimate that this intervention could reduce absence among girls by 6.1 days per girl per year for HP & WT and 6.8 days for HP & WT and sanitation. We found no evidence that our intervention had a significant impact on secondary impact measures: test scores and enrolment (Figures 3 and 4).

Table 3 Pupil-reported 2-week absence at baseline and follow-up and roll-call data at follow-up by intervention status and geographical strata

		Pupil-reported		Pupil-reported (Girls)		Roll-call
Geographical strata	Intervention package	Baseline n = 2595	Follow-up n = 3394	Baseline n = 1227	Follow-up n = 1640	Follow-up n = 135
Nyando/Kisumu	Hygiene promotion & water treatment (HP & WT)	16.3 (1.8)	4.8 (1.1)	14.5 (3.8)	3.7 (1.3)	11.1 (2.8)
	HP & WT + Sanitation	18.3 (3.8)	6.9 (2.0)	15.9 (4.3)	5.9 (2.9)	8.8 (1.4)
	Control	27.0 (4.2)	4.5 (0.8)	27.1 (6.6)	3.7 (1.3)	12.3 (1.2)
Rachuonyo	HP & WT	24.5 (2.4)	17.8 (2.4)	25.9 (3.9)	15.2 (2.2)	12.0 (1.4)
	HP & WT + Sanitation	16.5 (2.8)	15.2 (2.7)	18.0 (4.4)	19.0 (3.4)	9.9 (0.8)
	Control	17.4 (3.0)	22.6 (2.9)	15.1 (4.5)	28.2 (4.8)	13.2 (1.9)
Suba	HP & WT	24.6 (3.4)	14.3 (2.1)	24.8 (4.1)	16.9 (3.3)	12.2 (1.6)
	HP & WT + Sanitation	30.3 (4.3)	21.0 (3.3)	37.9 (7.7)	22.8 (4.1)	15.6 (2.3)
	Control	28.9 (3.4)	23.0 (3.4)	26.6 (4.8)	24.3 (3.8)	16.8 (2.6)
All regions	HP & WT	22.2 (1.6)	12.3 (1.4)	22.1 (2.5)	11.9 (1.6)	11.8 (1.1)
	HP & WT + Sanitation	21.5 (2.5)	13.8 (1.7)	23.3 (3.9)	15.2 (2.3)	11.3 (1.0)
	Control	24.4 (2.3)	16.2 (1.8)	22.8 (3.3)	18.2 (2.6)	14.1 (1.2)

Data are mean % (SE) for 2-week pupil absence accounting for survey weights. Roll-call data are mean % (SE) of children absent from entire school enrolment records aggregated at the school-level data.

Table 4 Model of pupil-reported absence for schools that received hygiene promotion (HP), water treatment (WT), and sanitation (San) vs. control schools by geographic strata ($n = 5{,}989$)

	Overall			Girls only			Boys only		
Variable	OR	95% CI	*P*	OR	95% CI	*P*	OR	95% CI	*P*
Full model									
Treatment effect: All strata - HP&WT[#] *(Q_1)*	0.81	0.49 – 1.34	0.43	0.63	0.31 – 1.27	0.19	1.04	0.59 – 1.85	0.59
Treatment effect: All strata - HP&WT + Sanitation[#] *(Q_2)*	0.97	0.55 – 1.64	0.90	0.78	0.37 – 1.62	0.50	1.17	0.65 – 2.08	0.66
Stratified by geography									
Treatment effect: Kisumu/Nyando - HP&WT[#] *(Q_1)*	2.05	0.87 – 4.83	0.10*	2.17	0.47 – 10.00	0.32	1.85	0.63 – 5.41	0.26
Treatment effect: Kisumu/Nyando - HP&WT + Sanitation[#] *(Q_2)*	2.59	0.82 – 8.12	0.10	3.20	0.60 – 17.00	0.17	2.18	0.62 – 7.69	0.23
Treatment effect: Rachuonyo - HP&WT[#] *(Q_1)*	0.48	0.24 – 0.98	0.04**	0.23	0.09 – 0.63	0.01***	1.00	0.41 – 2.44	1.00
Treatment effect: Rachuonyo - HP&WT + Sanitation[#] *(Q_2)*	0.65	0.27 – 1.60	0.35	0.48	0.15 – 1.58	0.23	0.86	0.32 – 2.29	0.76
Treatment effect: Suba - HP&WT[#] *(Q_1)*	0.69	0.36 – 1.32	0.27	0.70	0.27 – 1.81	0.46	0.63	0.28 – 1.40	0.26
Treatment effect: Suba - HP&WT + Sanitation[#] *(Q_2)*	0.83	0.47 – 1.47	0.53	0.55	0.25 – 1.19	0.13	1.20	0.63 – 2.28	0.58
Interaction: HP&WT in Rachuonyo vs. Kisumu/Nyando	0.24	0.08 – 0.71	0.01**	0.11	0.02 – 0.67	0.02**	0.54	0.13 – 2.18	0.38
Interaction: HP&WT + Sanitation in Suba vs. Kisumu/Nyando	0.25	0.06 – 1.08	0.06*	0.15	0.02 – 1.17	0.07*	0.39	0.08 – 1.95	0.25
Interaction: HP&WT in Suba vs. Kisumu/Nyando	0.34	0.12 – 0.99	0.05**	0.32	0.05 – 1.96	0.22	0.34	0.09 – 1.30	0.12
Interaction: HP&WT + Sanitation in Suba vs. Kisumu/Nyando	0.32	0.09 – 1.16	0.08*	0.17	0.03 – 1.08	0.06*	0.55	0.13 – 2.27	0.41
Interaction: HP&WT in Rachuonyo vs. Suba	0.70	2.67 – 1.82	0.46	0.33	0.08 – 1.32	0.18	1.58	0.47 – 5.23	0.45
Interaction: HP&WT + Sanitation in Rachuonyo vs. Suba	0.78	0.27 – 2.27	0.66	0.88	0.21 – 3.64	0.86	0.71	0.22 – 2.32	0.58

[#] *Q_1 and Q_2 by geographic strata are the terms that indicate the effect of the intervention controlling for secular trend (time).*
P = *significance at $\alpha < 0.1$, **significance at $\alpha < 0.05$, ***significance at $\alpha < 0.01$.

Discussion

To our knowledge, this is the first cluster-randomized trial to assess a suite of school-based WASH interventions to detect differences in attendance in low-income settings. Our study found that interventions to improve water quality, hygiene behaviours and sanitation in schools reduced absence among primary school pupils in the two geographical strata that were less impacted by political upheaval. This decline in absence was in addition to any reduction gained from deworming – an approach shown to reduce absence by 25% among highly infected populations – which was performed for all children in both the intervention and control arms (Miguel & Kremer 2004). The implication is that WASH improvements may have similar effects in areas with lower worm burden where mass deworming is not prescribed. As an effectiveness trial of a real programmatic intervention, we believe these findings provide evidence that WASH improvements can have a substantial impact on absence among girls (Habicht *et al.* 1999). The magnitude of our results is consistent, although higher than other studies of school WASH interventions (Bowen *et al.* 2007; O'Reilly *et al.* 2008; Blanton *et al.* 2010).

Poor school WASH conditions are often seen as disproportionately affecting girls, although few, if any studies have quantified this evidence (UNICEF, 2010). Our results suggest that WASH interventions can be effective in reducing this disparity; however, they do not clearly identify the mechanism by which girls benefit more. Potential explanations include greater reductions in exposure to faecal contamination leading to improved health; the role of improved toilets as an essential part of menstrual management, safety and privacy; and the role of handwashing water and soap to enable general cleanliness that more directly impacts girls (Pearson & Mcphedran 2008). Our findings suggest that for boys, improved WASH access does not mitigate key reasons for absence.

The intervention effect was not observed in Nyando/Kisumu. Sectarian violence following the post-election crisis of 2007 most severely impacted communities in this area near Kisumu City. There were widespread reports of

Table 5 Model of pupil-reported absence for schools that received hygiene promotion (HP), water treatment (WT), and sanitation (San) vs. control schools in Rachuonyo and Suba research strata overall and among girls

	Model 1 (n = 3880)			Model 2 (n = 3605)			Model 3 : Girls (n = 1723)		
Variable	OR	95% CI	P	OR	95% CI	P	OR	95% CI	P
Treatment effect: HP&WT vs. control# *(Q_1)*	0.61	0.37 – 1.00	0.052*	0.63	0.37 – 1.05	0.08*	0.42	0.21 – 0.85	0.02**
Treatment effect: HP&WT + Sanitation vs. control# *(Q_2)*	0.73	0.42 – 1.28	0.273	0.71	0.39 – 1.28	0.26	0.47	0.21 – 1.05	0.07*
Baseline imbalance: HP&WT vs. control	1.08	0.75 – 1.54	0.677	0.95	0.63 – 1.42	0.79	1.02	0.56 – 1.88	0.94
Baseline imbalance: HP&WT + Sanitation vs. control	1.00	0.63 – 1.58	0.987	0.90	0.60 – 1.36	0.63	1.14	0.62 – 2.10	0.66
Secular trend: Final vs. baseline	0.98	0.68 – 1.40	0.915	0.95	0.64 – 1.39	0.78	1.38	0.78 – 2.44	0.26
Grade				0.72	0.67 – 0.77	<0.001	0.71	0.63 – 0.79	<0.001
Gender: girls vs. boys				1.19	0.97 – 1.44	0.09*			
Pupils per teacher				1.00	0.99 – 1.01	0.48	1.01	0.99 – 1.02	0.27
School has electricity				1.61	0.97 – 2.69	0.07*	2.26	1.16 – 4.39	0.02**
School has cement floors				0.85	0.62 – 1.15	0.29	0.80	0.54 – 1.18	0.25
Proportion of female headed household				0.83	0.42 – 1.66	0.60	0.64	0.26 – 1.60	0.34
Median time to school				1.00	0.98 – 1.02	0.68	1.00	0.98 – 1.02	0.85
Proportion of female head of household completed primary school				0.48	0.18 – 1.22	0.12	0.26	0.07 – 0.89	0.03**
Proportion of female head of household that used soap at home				0.40	0.17 – 0.92	0.03**	0.42	0.13 – 1.40	0.16
Proportion of household with protected water source				0.87	0.58 – 1.30	0.49	1.14	0.67 – 1.95	0.62
Proportion of household with latrine				0.61	0.30 – 1.26	0.18	0.78	0.31 – 1.97	0.60
Mean of latrine cleanliness score				0.94	0.79 – 1.10	0.45	0.81	0.64 – 1.01	0.06*
Proportion of household in poorest SES quintile				0.71	0.16 – 3.09	0.64	0.22	0.03 – 1.57	0.13
Mean asset score				0.88	0.26 – 2.94	0.83	0.55	0.09 – 3.23	0.50

These variables are the key impact terms that indicate the effect of the intervention (Q_1) = water treatment and hygiene promotion, WT&HP; (Q_2) = WT&HP + Sanitation, since they show the impact on absence controlling for the effect of the program (intervention vs. control) and the secular trend between data collection rounds (follow-up vs. baseline).
P = *significance at $a < 0.1$, **significance at $a < 0.05$, ***significance at $a < 0.01$.

killing, destruction of property and looting in and around the city and nearby commercial farmland, resulting in considerable migration, a point supported by our data (Gettlemen 2008). Schools were closed for 4 months during the study period. However, the influence of widespread violence on our study could not be isolated.

That we did not see an impact on test scores or enrolment is not surprising. Given the advent of free primary education in Kenya, it is unlikely that a programme that only improves WASH will overcome poverty or other barriers to enrolment among children that are not currently attending school.

The intervention was effective in improving availability of drinking and handwashing water, soap and cleanliness of latrines. Water availability was enhanced even in schools that did not receive water supply improvements. However, the programme was unable to reach the standard of complete access to all of these factors together in many schools; and there was considerable heterogeneity in the effect of the intervention from school to school. Differential uptake of the intervention may be due to a variety of pre-existing, unmeasured confounders, such as level of community engagement, school leadership and success of the programme delivery.

The effects of single *vs.* multiple WASH interventions are debated in the literature. Our data revealed no significant differences between those schools that received WT and HP and those that received additional sanitation infrastructure. While our findings are consistent with the results in meta-analyses from Esrey (1985) and Fewtrell and

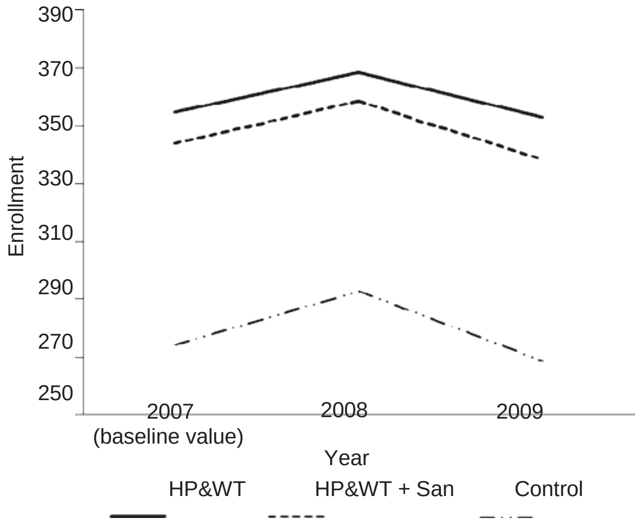

Figure 3 Pupil enrolment by intervention arm.

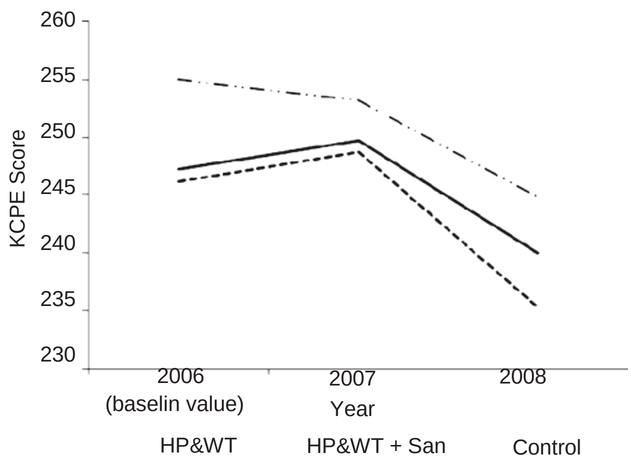

Figure 4 Kenya Certificate of Primary Education test results by intervention arm.

Colford (2005) of no added benefit in diarrhoea reduction from multiple interventions that improve WASH conditions, alternative explanations suggest caution in drawing similar conclusions from our findings. One potential explanation is that the sanitation intervention may not have been sufficient in number or quality. Only 29% of schools met the GoK recommended pupil-to-latrine ratio. Among sanitation schools, the mean ratio of acceptable latrines to pupils was >1:50. The benefit of sanitation as an amenity that encourages girls to attend may also depend on the cleanliness of the facility. Another explanation is that the pathogen exposure reduction benefits of sanitation may be conditional upon having adequate hygiene. Of the schools receiving improved sanitation, only 44% had handwashing water and soap at follow-up. The mechanisms whereby compliance determines treatment effect deserve further exploration. Finally, our data suggest that our simple hygiene intervention improved sanitation conditions, perhaps eclipsing the expected benefit from additional facilities. This suggests a need for programmatic and policy emphasis on ensuring availability of soap and cleanliness of latrines, rather than just supplying infrastructure. Hygiene education seems critical for achieving impact, both independently and in concert with hardware interventions.

Limitations

There are a number of key limitations to this study. In terms of internal validity, the precipitous drop in absence between baseline and follow-up in one geographical stratum required us to use a stratified analysis that limited the power of the study to detect differences between intervention and control groups overall. The use of self-report data is subject to recall bias. Lack of intervention blinding may have induced measurement bias towards more acceptable answers. Further, follow-up data were collected at a time when pupils may have been more likely to attend for test preparation; data could therefore underestimate the potential impact of the intervention at other times. As roll-call is for 1 day only, and recall is for 2 weeks, we expect smaller numbers for roll-call, yet roll-call absence was higher than reported 2-week absence for Nyando/Kisumu.

The study also presents limitations that may impact external validity. Chief among these was the considerable disruption to implementation from the post-election violence discussed above. A second key limitation is that such interventions are heavily dependent on local participation and capacity of local staff, resulting in heterogeneity of implementation. It is also significant that the intervention called for yearly deworming of all students, an intervention proven to improve school attendance that may have contributed to a reduction in effect size and study power, as deworming would have reduced absence among the control schools (Miguel & Kremer 2004). Helminth infection is highly heterogeneous and clustered, and schools with higher baseline helminths levels may have benefitted more from deworming and shown greater reductions in absence from deworming (Brooker 2010).

Conclusion

Our study should be considered an effectiveness trial at a certain point in time and place that can help formulate policy and research questions for future work, rather than an efficacy trial with definitive findings applicable to all settings. We found compelling evidence of the impact of school-based WASH improvement on school absence for girls. Additional work is necessary to explain the mechanism of impact on girls: is it privacy, menstrual hygiene management, health, or something else entirely?

Substantial funding for WASH is focused on household provision of services for achievement of the Millennium Development Goals (United Nations 2010). However, our study points to the educational and health benefits of providing cost-effective WASH facilities in schools, and the explicit need to ensure high-quality HP and behaviour change approaches. The differential impact seen among girls highlights the need to consider the question of *who* benefits from WASH programming rather than simply *how many* (Rheingans *et al.* 2006).

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